doi: 10.14355/afl.2015.04.004

Spatial Evaluation of Plant Community Structure and Species Abundance Using TWINSPAN- PC ORD

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Abstract

There is need to explore the relationships and assess plant community census and patterns. In 18 grid plots in Dalingshan forest was used to conduct plant community structure and abundance evaluation. Plant and vegetation community types were analyzed using TWINSPAN- PC ORD (Two-way Indicator Species Analysis). A field survey was conducted and GPS based map was established. Field/grid map and TWINSPAN were employed to identify species abundance within spatial nutrient distributions. The study was designed to grid the site at 200 x 200 m spatial patterns. 18 grid plots were adopted to identify species abundance and characteristics and total of 99 species observed. TWINSPAN using the PC-ORD software was applied to develop four groups plot dendogram. The entire field procedure was used to establish species census and abundance spreadsheet which aided census of species at medium abundance identified *Rhuschinensis (Rch)* of abundance (95), *Adiantumcapillus (Aca)* abundance (90), *Blechnumorientale (Bar)* abundance (87) and *Agaratumconyzoides (Aco)* abundance (80). Species of optimum abundance identified *Hedyotisauricularia (Hau)* 3767, *Miscanthussinensis (Msi)* 2520, *Lophatherumgracile (Log)* 833 and *Mikaniamicrantha (Mmi)* 803 respectively. In furtherance, the results showed that species of floristic composition identified at optimum abundance in percentage (%) include *Hedayotisauricularia (32%), Mikaniamicrantha (21%), Hophatherumgracile (7%) and Mikaniamicrantha (7%).* This study thereby suggests that the species evaluation can be utilized for further studies on multifactor ecosystem responses towards regional ecological restoration. However, it is critically required to conduct further studies on spatial patterns of soil nutrient distributions in both forest regimes and at regional level.

Keywords

TWINSPAN, PC –ORD, Species Abundance, Plant Community Structure, Plant Census, Spatial Patterns, DalingshanForest, Guangdong Province China

Introduction

Investigations on plant competition and diversity, which are substantially affected by spatial interactions, nutrient distribution and vegetation heterogeneity have been documented by Jackson and [1] and [2], [3] in forest dynamics explicitly considered under spatial and temporal scales. Such vegetation dynamics models developed include [4] that defined spatial and temporal scale variability factors. The link among plant community composition, nutrient distribution and competition for underground nutrient (resources) and differences in the temporal spatial distribution within vegetation variability has attracted extensive literature reports, such as [5], [6],[7] and [8] to mention a few. Some physiological factors of a given forest region such as topography, terrain, soil, climate and agricultural practices as well as the effect of long-term human activity and forest plant community type protection are becoming complex factors. Some researchers had focused on variables of indicators of spatial position, soil, topography and environmental factors using TWINSPAN to analyze plant community types. Forest and environmental ecologists are finding plant community and structure pattern very important, however, it is attracting greater focus and in a broad sense that plant community distribution pattern and abundance are influenced by many environmental factors such as climate, soil and topographic features. Generally, natural plant communities are distributed continuously that composed of different plant community successions. The successions in plants community do respond to ecological and environmental factors at different times.

Considering the effect of climate change and global warming, plant community and vegetation abundance in both local and regional forest becomes an important focus for researchers. Multivariate analysis application plays an important role in understanding the relationship between plant community distribution and vegetation abundance that may be as a result of ecological and environmental factors. TWINSPAN, DCA (Detrended Correspondence Analyses), CCA and DCCA in various studies of [9],[10] and [11],[12] have been widely employed in understanding vegetation distribution and abundance which has become the analytical approach in this study. The vegetation and plant census and abundance in Dalinghshan Forest Region of Guangdong Province of China were conducted. This field study brought some pertinent issues that were investigated such as: 1) what may be responsible to plant community abundance? 2) The plant census identification as the relationship between the plant community and environment.3) what could be the determining factors in understanding plant community distribution and patterns? It becomes very important to conduct this field study that is useful in quantitative ecology and forestry thereby providing ecological and environmental understanding of plant and vegetation abundance in a given forest region. It is very significant in forest vegetation management and forest ecosystem protection and thereby supports the knowledge for forest restoration practices.

Methodology

Field Sampling and Survey

A site recognizance survey was conducted with the aim of providing baseline physical assessment of the site; previewing the distribution of vegetation canopy and ephemeral species growth. The area has an average elevation of 120m a.s.l. A geographic position systems (GPS) location digitized contour topographic map of the area was designed into 20 grids (200 x 200 m) whereby 18 grid cells were principally utilized (Fig. 1). Within this period secondary information was sourced to understand the land use and management pattern and any vegetation inventory of the area. A location digitized contoured topographic map of the area was designed into 20 grid measured at 200 x 200 m. The study accounting grids were enumerated from 1-18 formation. The area sampling map was developed to determine physical nature of the area such as slope and topographical nature of the entire site. The UTM coordinates of the grid lines were recorded and within each transect of the GPS for which the methods of [13] were good reference concept background. The nautical position was identified under topographical elevation (49 Q UTM) of North and South direction. Furthermore, this is intended to be utilized in vegetation enumeration survey of the site. Ground–based vegetation data was also applied under "field plot" grid pattern which was further described by [14]. Ground-based vegetation accounts for each plant within the 200 x 200 m transect recorded as to its species. These 18 complete square sized grid transect were used to classify vegetation and species series as documented by [15]. Considering the effects of dominant and common species on communities, species whose frequency was less than 5% were removed and species whose frequency was equal or more than 5% were preserved.

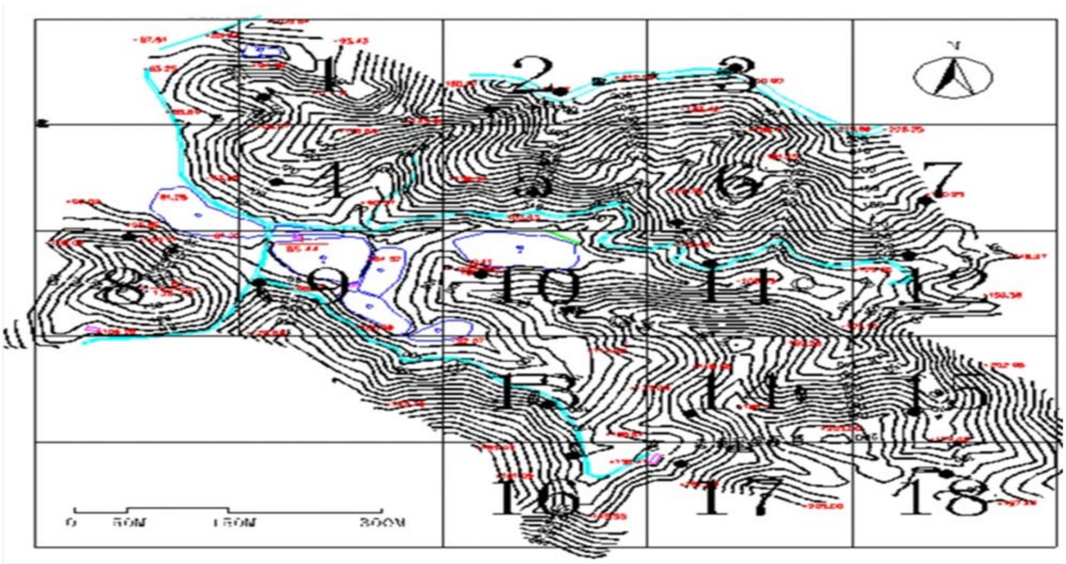

FIG.1.TOPOGRAPHIC GRID MAPPING OF THE AREA DEPICTING SAMPLING GRIDS OF THE SITE

Twin Span and Quantitative Analysis Method

TWINSPAN was used to classify the plant community types and DCCA was used to ordinate them. These methods were aimed to study the relationship between communities and environmental factors though the abundance and census of plants vegetation formed the cardinal interest of this study and left the opportunity for further investigation. DCCA ordination particularly emphasized investigating ecological gradients of the region. The eigen values of DCA and DCCA were compared at the same time to analyze whether there exit some important environmental factors which have been omitted though this study was not focused on the influence of environmental factors.Various methods and techniques have been used to evaluate spatial characteristics of both vegetation characteristics and communities and nutrient distributions. Such methods include nugget, range and sill parameters of spherical model variograms which were prominently applied by [16] on characterization of spatial structure of vegetation communities from geostatistical approach/technique. In as much ground survey is a strategic vegetation assessment; this concept forms a strong background of our field grid pattern in evaluating and assessing species dominance in Dalingshan site. The geostatistical technique in contrast is usually designed to identify and quantify spatial plant and vegetation characteristics. However, vegetation spatial patterns of a region can be characterized quantitatively by semi-variogram (variogram). The collection of field species data was subjected to PC-ORD for TWINSPAN analysis, [17] generating end groups of four homogeneous plots that represent discrete vegetation units that form the dendogram (Figure 2). TWINSPAN is a program for classifying species and samples, producing an ordered two-way table of their occurrence. The process of classification is hierarchical; samples are successively divided into categories, and species are then divided into categories on the basis of the sample classification.

Vegetation Cover and Abundance Assessment

A plant census at the site (enumeration) was conducted to identify within the sequence of the accounted 18 grid over the site. The enumeration of species was conducted and that establishes a spread sheet that identified 94 plant species. In the analysis method above, clustering was carried out using TWINSPAN 2.3; forward selection, DCCA, partial CCA and Monte Carlo test were realized using ANOCO 4.5 made by TerBraak.

Results

Classification of Vegetation/Plant Community Types

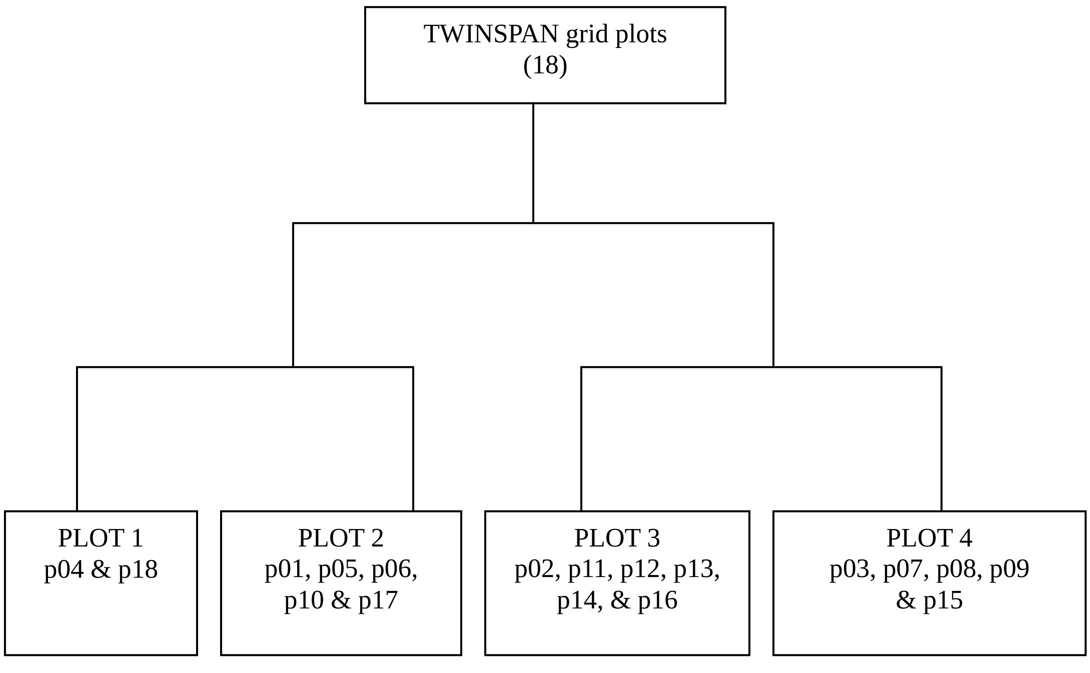

FIG. 2 GROUND CLASSIFICATION OF VEGETATION DENDOGRAM

Plant community types were divided by TWINSPAN and the results can be seen in Fig. 2. They were classified into 18sampling grids and were divided into 4 plots for vegetation dendogram and classification. The vegetation characteristics and classification based on TWINSPAN program from PC-ORD within 18 sampling plots of 4 groups of the study site hereby identified plant species dominant provided the species abundance and variability. This approach was also utilized to present a census of plant vegetation.

TABLE 1 SPECIES CENSUS IDENTIFIED (99) MARKED (SERIAL) INDICATED WITH SCIENTIFIC NAME ABBREVIATIONS

Site species census (99) plants across 18 grid of 4 groupings- serial and Latin abbreviations									
1 *Aau*	2 *Aca*	3 *Aco*	4 *Adi*	5 *Aho*	6 *Aja*	7 *Ake*	8 *Ama*	9 *Aph*	10 Avi
11*Anv*	12 *Bbi*	13 *Bfr*	14 *Brf*	15 *Bja*	16 *Bor*	17 *Bpi*	18*Bpu*	19 *Cal*	20 *Cbi*
21*Cbu*	22 *Cca*	23*Cco*	24 *Cfo*	25 *Cgr*	26 *Pa*	27 *Dci*	28 *Ddi*	29 *Den*	30*Dhe*
31 *Eca*	32 *Ech*	33 *Eja*	34 *Ela*	35 *Ele*	36 *Eso*	37 *Fhi*	38 *Fho*	39 *Gja*	40 *Han*
41*Hau*	42 *Hbi*	43*Hco*	44 *Hdi*	45 *Ias*	46 *Ich*	47 *Ici*	48 *Icy*	49 *Lca*	50 *Lch*
51 *Lgl*	52 *Lir*	53 *Lja*	54*Lmo*	55 *Log*	56*Map*	57*Mca*	58*Mco*	59*Mdo*	60 *Mmi*
61*Mpa*	62 *Mpu*	63*Mse*	64 *Msi*	65*Mup*	66*Oco*	67*Oun*	68 *Paq*	69 *Pch*	70 *Pco*
71*Pem*	72 *Pfa*	73 *Phc*	74 *Phe*	75 *Phy*	76 *Plo*	77 *Ppe*	78 *Pru*	79 *Psc*	80 *Pts*
81*Pth*	82*Pur*	83*Rch*	84*Rin*	85*Rre*	86 *Rto*	87 *Sac*	88 *Sch*	89 *Sdi*	90 *Sdu*
91 *She*	92 *Slo*	93 *Sno*	94 *Sse*	95 *Sth*	96 *Tor*	97 *Ulo*	98*Win*	99 *Yja*	

The TWINSPAN and vegetation census identified 99 herbaceous plant species

The species census and abundance was further assessed where the dendogram here in fig.3 outlined species census and abundance spreadsheet.

Species (Scientific Names)	Co	Abund
Species		
Anemone vitifolia	*Anv*	5
Cocciniagrandis	*Cgr*	5
Fokieniahodginsii	*Fho*	5
Polygonumhydropiper	*Phy*	5
Puerarialobata	*Plo*	5
Cassia alata	*Cal*	6
Phyllanthuscochinchinensis	*Phc*	6
Sageretiathea	*Sth*	6
Desmodiumheterocarpum	*Dhe*	9
Lantana montevidensis)	*Lmo*	9
Alpinia japonica	*Aja*	10
Aneilemakeisak	*Ake*	10
Alocasiamacrorrhiza	*Ama*	10
Baeckeafrutescens	*Bfr*	10
Bidenspilosa	*Bpi*	10
Dioscoreacirrhosa	*Dci*	10
Gardenlajasminoides	*Gja*	10
Hedyotiscorymbosa	*Hco*	10
Hedyotisdiffusa	*Hdi*	10
Ischaemumciliare	*Ici*	10
Litchi chinens	*Lch*	10
Litsearotundifolia var. oblongifolia	*Lir*	10
Microcospaniculata	*Mpa*	10
Mimosa sepiaria	*Mse*	10
Pterisfauriei	*Pfa*	10
Scopariadulcis	*Sdu*	10
Stenotaphrumhelferi	*sth*	10

Sapiumsebiferum	*Sse*	10
Euryachinensis	*Ech*	11
Helicteresangustifolia	*Han*	11
Phyllanthusurinaria	*Pur*	11
Raphiolepisindica	*Rin*	12
Eriobotrya japonica	*Eja*	13
Cinnamomumburmanii	*Cbu*	14
Eupatorium catarium	*Eca*	14
Opliamenusundulatifolius	*Oun*	15
Stephania longa	*Slo*	15
Tremaorientalis	*Tor*	15
Acacia auriculaeformis	*Aau*	16
Emilia sonchifolia	*Eso*	16
Urenalobata	*Ulo*	16
Ixorachinensis	*Ich*	18
Alternantheraphiloxeroides	*Aph*	20
Imperatacylindrica	*Icy*	20
Mallotusapelta	*Map*	20
Melastomadodecandrum	*Mdo*	20
Pterissemipinnata	*Pts*	20
Synedrellanodiflora	*Sno*	20
Youngia japonica	*Yja*	20
Bruceajavanica	*Bja*	21
Phyllanthusemblica	*Pem*	21
Aporosadioica	*Adi*	22
Amaranthusviridis	*Avi*	22
Breyniafruticosa	*Brf*	22
Psychotriarubra	*Pru*	22
Cassia bicapularis	*Cbi*	23
Pterospermumheterophyllum	*Phe*	23
FicushirtaVahl	*Fhi*	25
Conyzacanadensis	*Cca*	28
Cyclosorusparasiticus	*Cpa*	30
Polygonumperfoliatu	*Ppe*	35
Paederiascandens	*Psc*	35
Rhodomyrtustomentosa	*Rto*	35
Wikstroemiaindica	*Win*	35
Ilex asprella	*Ias*	38
Oxalis corniculata	*Oco*	41
SidaacutaBurm	*Sac*	41
Evodia lepta	*Ele*	42
Paspalumthunbergii	*Pth*	54
Mikaniacordata	*Mco*	60
Clerodendrumfortunatum	*Cfo*	61
Pteridiumaquilinum	*Paq*	61
Lantana camara	*Lca*	64
Dianellaensifolia	*Den*	67
Mimosa pudica	*Mpu*	67

Paspalumconjugatum	*Pco*	72
Litseaglutinosa	*Lgl*	76
Embelialaeta	*Ela*	77
Ageratum conyzoides	*Aco*	80
Blechnumorientale	*Bor*	87
Adiantumcapillus-veneris	*Aca*	90
Rhuschinensis	*Rch*	95
Polygonumchinensis	*Pch*	124
Mussaendapubescens	*Mup*	141
Bidensbipinnata	*Bbi*	148
Melastomacandidum	*Mca*	164
Lygodiumjaponicum	*Lja*	180
Rhynehelytrumrepens	*Rre*	200
Smilax china	*Sch*	253
Borreriapusilla	*Bpu*	335
Hedyotisbiflora	*Hbi*	377
Commelinacommunis	*Cco*	433
Dicranopterisdichotoma	*Ddi*	723
Ageratum houstonianum	*Aho*	742
Mikaniamicrantha	*Mmi*	808
Lophatherumgracile	*Log*	833
Miscanthussinensis	*Msi*	2520
Hedyotisauricularia	*Hau*	3767

FIG.3 SPECIES CENSUS AND ABUNDANCE SPREADSHEET

Classification and Characteristic Composition of Floristic Species

Woody vegetation cover herbaceous grassland was observed over the site and in terms of canopy extent the most extensive (optimum species) were identified as in table 3 below. Plant individual species and community associations have been proved and linked to nutrient spatial distribution and ground elevation gradients. However, it has been evident that dominant species may affect composition through modification of spatial local environment as reported by [18], 19]. This phenomenon accounts for dominance and abundance of species of table 1, figures3 and 4.

TABLE 3: SITE OPTIMUM COMPOSITION (CENSUS) AND CLASSIFICATION OF VEGETATION.

Adiantumcapillus-veneris	*Aca*	90
Rhuschinensis	*Rch*	95
Polygonumchinensis	*Pch*	124
Mussaendapubescens	*Mup*	141
Bidensbipinnata	*Bbi*	148
Melastomacandidum	*Mca*	164
Lygodiumjaponicum	*Lja*	180
Rhynehelytrumrepens	*Rre*	200
Smilax china	*Sch*	253
Borreriapusilla	*Bpu*	335
Hedyotisbiflora	*Hbi*	377
Commelinacommunis	*Cco*	433
Dicranopterisdichotoma	*Ddi*	723
Ageratum houstonianum	*Aho*	742
Mikaniamicrantha	*Mmi*	808
Lophatherumgracile	*Log*	833
Miscanthussinensis	*Msi*	2520
Hedyotisauricularia	*Hau*	3767

Discussion and Conclusions

Elevation Vegetation and Floristic Abundance

This investigation was not focused on elevation (topography) and but it has been reported on a global assertion that plant interactions along elevation are influenced by gradients from competition to facilitation such as abiotic stress increases[20], [21], as such interactions within biotic and abiotic factors are important in determining species distributions. Our expectation was overall intermix of species though naturally species tend to be of abundance within even gradient which may be related to stability of nutrients and canopy cover. Generally, our study is in confirmation that both nutrients distribution and soil factors do account for species abundance and characteristics. This is in line with the report of [22] that conforms to positive correlation between species richness and site moisture. We identified in figure 1, that square grid number 8, 9, 10, 12, 13, 14, 16, 17 and 18 to share more even gradient and accommodate more plant species abundance. Vegetation cover assessment is considered under soil spatial nutrients and species composition differs between vegetation (forest) types that has greater link to ecological factors. This may be responsible to dominance/abundance of species as in table 2. Plant (vegetation) communities may not be stable over range of environmental conditions but spatial nutrient variability constitute a determining factor, this assertion has been supported by the fact that ecosystem stability is increased by the presence of many functional groups as reported by [23].Our findings showed that species pattern of floristic distribution gives an insight of the least presence–absence data as in tables 1 and 2. In furtherance, floristic abundance and composition in table 3, showing percentage value of dominant species (Hau 3767 (32%), Msi 2520 (25%), Log 833 (7%), Mmi 808 (7%), Aho 742 (6%) and Ddi 723 (6%)

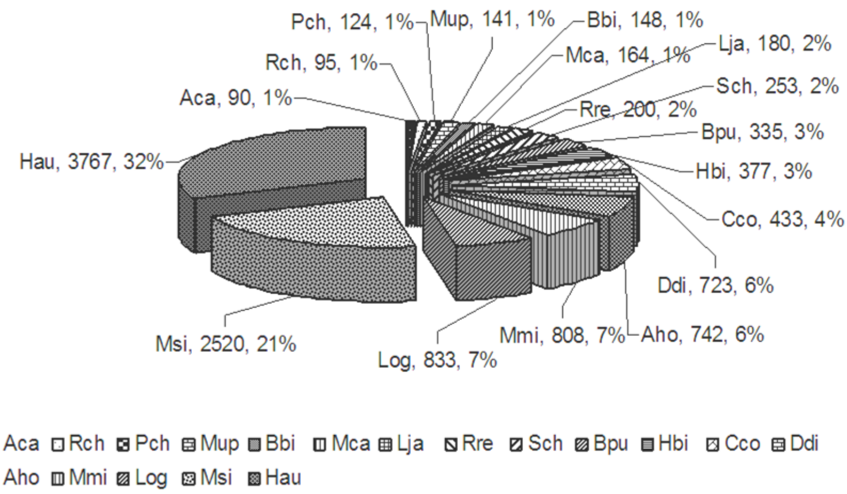

FIG. 3 DOMINANCE AND SPATIAL SPECIES ABUNDANCE ACROSS THE SITE

Generally, this study evaluated majorly spatial assessment in distribution of vegetation but it is worth taking into consideration that regional soil conditions may influence spatial distribution of nutrients that in-turn influences species abundance and dominance. This study is useful for appropriate recommendation for forest management; regional nutrient soil fertility regime management and plant species/vegetation cover change assessment. Species identified that share greater abundance rated in percentage include *Hedayotisauricularia (32%), Mikaniamicrantha (21%), Hophatherumgracile (7%) and Mikaniamicrantha (7%).* The study revealed unique spatial patterns of soil nutrient distribution in Dalingshan and species abundance may be adapted to a broad range regional vegetation and floristic advantage. This study hereby suggests that the species can be utilized for further studies on multifactor ecosystem responses towards regional ecological restoration. Generally, this study is strategic to generate understanding of a local vegetation pattern which could serve a good predictive and environmental factor that best correlate with patterns (spatial distribution) of regional species composition.

Distribution of Species Richness

Distribution and vegetation abundance is most likely regulated by two or more environmental gradients. Species richness of forest ecosystem is determined mainly by forest management systems, protection and the species pool

[24]. Area and geometry are amongst most important factors influencing species richness along topographic gradient [25]. Various studies had identified the influence of environmental factors contributing to distribution of plant pattern and community census. Based on the analysis of TWINSPAN, the plant communities were classified into 4 different abundance and census vegetation dendogram. However, the results infer that there may be significant ecological and environmental factors that may be responsible for the vegetation population and abundance percentage. The ordination of the plant communities at any stage portrays the relationship between community distribution patterns and plant communities. The plots aggregated together in their abundance shows plant community structures thereby are similar not only in species composition but reflecting to forest soil nutrient stability. Vegetation patterns and species abundance using DCA and CCA ordination techniques that were conducted in Dalingshan Forest Region showed that results obtained interpreted community types and similarity in species abundance that supported the TWINSPAN classification results. The results indicated that the ordination analyses proved useful in confirming and clarifying vegetation relationships within and between the classified groups [26]. Difference of plant species composition along any forest region can be attributed to soil conditions for plant growth, nutrient availability and distribution as well as forest management regimes.

REFERENCES

[1] Caldwell (1993) Jackson, RB, MM Caldwell. 1993. The scale of nutrient heterogeneity around individual plants and its quantification with geostatistics. ***Ecology*** **74**:612-614

[2] Biondini. Mario. E and Grygiel Carolyn. E (1994) Landscape Disreiburion of Organisms and the Scaling of Soil Resources. American Naturalist, Volume 143, Issue 6, 1026-1054

[3] Bartolome, J.W. 1989. Local temporal and spatial structure. P. 73-80. In: Huenneke, L.F. and H.A. Mooney (ed.) Grassland structure and function: California annual grassland. Kluwer Acad. Publ., Dordrect, Netherlands.

[4] Bazzaz *F*, Sultan *SE (*1987*)* Ecological variation and the maintenance of plant diversity. In: Urbanska K, editor. Differentiation Patterns in Higher Plants.

[5] C. L. Turner and A. K. Knapp 1996.Responses of a C_4 Grass and Three C_3 Forbs to Variation in Nitrogen and Light in Tallgrass Prairie. Ecology 77:1738–1749. http://dx.doi.org/10.2307/2265779

[6] Casper, BB, & RB Jackson. 1997. Plant competition underground. ***Annual Review of Ecology and Systematics*** **28**:545-570 dx.doi.org/10.1146/annurev.ecolsys.28.1.545.

[7] Hooper DU, Vitousek PM (*1998*) Effects of plant composition and diversity on nutrient cycling. ... to manipulation of pH and nutrient status in coniferous forest soil.

[8] Jiang H. DCA ordination, quantitative classification and environmental interpretation of spruce and fir communities in Northwest Sichuan and South Gansu. ActaPhytoecologicaSinica, 1994, 18(3): 209–218.

[9] Li B, Zhang J T. Ecological interaction of vegetation community on Loess Plateau. 2003: Journal of Agro-Environment Science, 22(4): 471–473.

[10] TerBraak C J F, Prentice I C.A theory of gradient analysis. Advances in Ecological Research, 1988, 18: 271–317.

[11] TerBraak C J F, Smilauer P. CANOCO reference manual and user’s guide to Canoco for Windows: Software for canonical community ordination (Version 4). Ithaca, NY, US: Microcomputer Power, 1998.

[12] Prentice I.C 1988, paleoecology and plant-population dynamics, *trends in ecology & evolution*, vol: 3, pages: 343-345, issn: 0169-5347

[13] Hill, M.O. 1979a. TWINSPAN- A Fortran Program for arranging Multivariate Data in an Ordered Two-Way Table by Classification of the Individuals and Attributes. Cornell Univ. Ithaca. NY.

[14] Hill, M.O. 1979b. DECORANA. A Fortran Program for Detrended Correspondence Analysis and Reciprocal Averaging.Cornell Univ. Ithaca. NY.

[15] Colles, A., L. H. Liow, and A. Prinzig. 2009. Are specialists at risk under environmental change? Neoecological, paleoecological and phylogenetic approaches.*Ecology Letters* 12(8):849-863. http://dx.doi.org/10.1111/j.1461-0248.2009.01336.x

[16] Bruce W. Hoagland and Scott L. Collins *Oikos*1997. Gradient Models, Gradient Analysis, and Hierarchical Structure in Plant Communities Vol. 78, No. 1 (Feb., 1997), pp. 23-30 Published by: Wiley on behalf of Nordic Society Oikos DOI: 10.2307/3545796 Page Count: 8 URL: http://www.jstor.org/stable/3545796

[17] Choler, P., Michalet, R., Callaway, R.M., 2001. Facilitation and competition on gradients in alpine plant communities.Ecology 82, 3295–3308.

[18] Ragan M. Callaway, R. W. Brooker, Philippe Choler, ZaalKikvidze, Christopher J. Lortie, Richard Michalet, Leonardo Paolini, Francisco I. Pugnaire, Beth Newingham, Erik T. Aschehoug, Cristina Armas, David Kikodze[4]& Bradley J. Cook (2002), Positive interactions among alpine plants increase with stress *Nature*417, 844-848 doi:10.1038/nature00812;

[19] Allen, R.G., F.N. Gichuki, and C. Rosenzweig, 1991: CO_2-induced climatic changes and irrigation-water requirements. *J. Water Resour. Planning Mgt.*, **117**, 157-178

[20] Naeem, S. (1998). Species redundancy and ecosystem reliability.Conserv. Biol., 12, 39–45.

[21] Pausas, J.G. and M.P. Austin. 2001. Patterns of plant species richness in relation to differentenvironments. *J. Veg. Sci.*, 12: 153-166.

[22] Leps, J. 2004. What do the biodiversity experiments tell us about consequences of plant species loss in the real world? *Basic. App. Ecol.*, 5: 529-534.

[23] Sanders, N.J. 2002. Elevational gradients in ant species richness: area, geometry and Rapoport's rule. *Ecography*, 25: 25-32.

[24] Franklin J, Wiser S K, Drake D R. Environment, disturbance history and rain forest composition across the islands of Tonga, Western Polynesia. Journal of Vegetation Science, 2006, 17(2): 233–244.

[25] Liu S L, Ma K M, Fu B J,.The relationship between landform, soil characteristics and plant community structure in the Donglingshan Mountain Region, Beijing.ActaPhytoecologicaSinica, 2003, 27(4): 496– 502.

[26] Shupe, S.M. 2005. Multivariate characterization of Sonoran Desert vegetation in southwest Arizonausing US Army field data.*Plant. Ecol.*, 176: 215-235.